// THE OHIO JOURNAL OF SCIENCE

VOL. XXXIX MARCH, 1939 No. 2

EXTRAORDINARY DEVELOPMENTS AT OR NEAR THE ENDS OF EVOLUTIONARY SERIES.

STUDIES IN DETERMINATE EVOLUTION, XI*

THE LATE JOHN H. SCHAFFNER

When the taxonomic groups of plants are arranged in proper phylogenetic series in agreement with their advancement in complexity of reaction systems, a remarkable situation becomes evident that could not be recognized so long as taxonomy was developed along the lines of the old, haphazard teleological hypothesis of origins. It is found that at or near the ends of many orthogenetic series, especially the higher ones, one frequently meets with very unusual, peculiar, or extraordinary characters and complexities which are not in evidence or only very rarely so in the lower levels of the series. Not only are these extreme developments unusual and particular but they are frequently bizarre and grotesque, each series usually having some characteristic structures or reactions not evolved in other series, even though the general evolutionary developments have been essentially similar. Curiously enough these extraordinary characters were formerly often taken to indicate primitiveness; as for example, *Zea mays* L. was put at the bottom of the grass series although it has a most remarkable array of unique and highly evolved characters.

When one studies a group of organisms from the phylogenetic point of view, it is always advisable to look for these unusual characters near the supposed limits of the main lines and near the ends of the various subordinate series. It is impossible at the present time to form an adequate conception of the cause or causes of this remarkable biological phenomenon, but it appears to be associated with highly specialized and com-

*Papers from the Department of Botany, The Ohio State University, No. 409.

plex aggregations of hereditary potentialities in the evolved protoplast. When the protoplast becomes filled, so to speak, with a great aggregation of hereditary potentialities these extraordinary mutations seem to occur very frequently when compared with the more uniform accumulation of characters appearing at the lower levels of the phyletic series.

In the present study a general view of some of these extraordinary forms is given, the examples being taken mostly from the higher, vascular plants. A few, however, are from the lower plant series in which remarkable structures are by no means absent.

Among the most bizarre forms are a number of advanced gastromycetous fungi; like *Dictyophora phalloides* Desv. This is a mushroom with a very fancy lace-like "petticoat." The lower true fungi are mostly composed of a loose, branching mycelium, which, although it may react to various stimuli as light, substratum, etc., seems to have only a very slight correlative interaction between the different mycelial branches. In the highest fungi, this property of unitary correlation between the hyphae becomes truly marvelous in the development of the fruiting body. The mycelial threads in their growth and branching weave patterns as astonishing in their complexity as a complicated tapestry. *Dictyophora phalloides* represents an extreme example of such reaction. It is difficult to believe that such a plant exists if one has never seen it. It has a pure white stipe, a cap of greenish color, and, as stated above, a white-lace-like petticoat, with polygonal and hexagonal meshes, suspended around the stipe below the spore-bearing body. It has, moreover, a most vile odor combined with its wonderful beauty of form and color.

There are various extreme culminations among the higher algal series. In the Characeae, or stoneworts, the species of *Chara* have very peculiar and complicated sex organs, especially the antheridium. The antheridium is spherical in shape and looks externally as if composed of solid tissue, but it is really a highly organized system of filaments with long branches coiled up in the inside, the individual cells of these filaments developing the spermatozoids. The antheridia are bright red in color in decided contrast to the nearby oogonia which are green, flask-shaped bodies covered with five spiral filaments. The sexual dimorphism of these gametangia in form, structure, and color is just as extreme, even though they develop side by side on the same branch, as the sex difference in various birds and other higher animals, which has been ascribed by the teleological selectionists to the causative operation of "sexual selection," one or the other mate being supposed to have a preference for fancy colors and unique forms. As stated, in *Chara* the red antheridia and green oogonia are situated on the same individual, but similar differences in color and form of parts surrounding the sex organs are also found in species of Polytrichum, which are among the most highly evolved unisexual mosses. The relative dimorphism is just as great as between a hen and a rooster. The absurdity of the sexual selection hypothesis becomes evident when applied to these mosses which have neither eyes nor brains with which to make a choice of mates; but in spite of great numbers of such contradictory cases, the "sexual selection" delusion has not yet entirely disappeared from a certain type of biological mind.

Our living species of *Equisetum* represent the surviving culmination type of a great group of plants that appeared far down in the geological scale. All the living species of Equisetum show an unusual development in the peltate sporophylls and in having highly hygroscopic, coiling elaters attached at one side of the spores, produced by the spiral splitting of the outer wall of the tetraspores. Another extreme condition in most of the species is the extraordinary development of silex in the cell walls, especially in the epidermis. The highest species, *Equisetum arvense* L., is an extraordinary plant because it, with its near relatives, shows an extreme dimorphism of its vegetative and reproductive, aerial shoots. The vegetative shoot is green and much-branched and survives until late autumn while the reproductive shoot is without green color, is unbranched, and dies in a few days after coming out of the ground. Such extreme dimorphism of the entire shoots is exceedingly rare in the plant kingdom.

In the Polypodiaceae, which represent the highest, homosporous, leptosporangiate ferns, an extremely unique and perfected type of sporangium, capable of throwing the spores a short distance, has developed. The heterosporous water ferns are the most advanced types in the fern phylum and also exhibit a number of unusual developments. *Azolla caroliniana* Willd. is a tiny, free-floating plant which has attained the extreme limit of leaf arrangement, the alternate, two-ranked system. In its microsporangia it develops peciular massulae, each containing several microspores. On the surface of these massulae anchor-like processes or glochidia with septate stalks are borne. Comparable masses of microspores or pollen, but of a different structure, are found in some orchids and in milkweeds, both of which groups represent extreme developments in their phyletic lines. *Salvinia natans* (L.) Hoffm. has remarkably developed floating leaves which tend to keep the plant right side up and in addition finely dissected leaves having the appearance of roots dangling into the water. In the genera *Marsilea* and *Pilularia* highly specialized sporocarps are developed which discharge their sporangia and spores by emitting a gelatinous, elastic band or cord to which the sporangia are attached. All these characteristics are unique in the plant kingdom.

A very bizarre condition is present in the higher species of *Selaginella* which represent the most advanced stage in the living Lepidophyta. In these species, the closed vascular bundles, whose chief function is the transfer of water through the plant body, are situated in tubular cavities filled with air in the ground tissue of the stem. The bundles are suspended in the middle of the tubes by means of filaments of cells passing from the walls of the tubes to the surface of the bundles. Compared with the usual stem structure, this arrangement of the tissues certainly represents an extraordinary mechanism.

In passing from the Pteridophyta to the Gymnospermae, one discovers a pronounced advance in the complexity of the general reaction system of the cell. One is prepared to meet with odd developments as soon as one encounters the more highly evolved genera. Among the highest of the Taxodiaceae is *Taxodium distichum* (L.) Rich. which has among other remarkable features the development of large woody outgrowths or "cypress knees" from the roots and highly specialized, herbaceous, annually deciduous, feather-like dwarf branches. It also has decidedly ornamental markings on the outer surface of the carpels of the globular cone. *Sciadopitys verticillata* (Thumb.) S. & Z., another advanced type of the Taxodiaceae, is remarkable for its dwarf branches with long double needle leaves.

Among the Pinaceae, the genus *Pinus* contains the species with the most complicated reaction systems and with some very unusual structures. The peculiar combination of needle leaves (some as in *P. palustris* Mill. up to 16 or more inches long), deciduous dwarf branches, fission embryos with extraordinary embryonic development, whorl of linear cotyledons, and in some species, as in *P. coulteri* D. Don. enormous, woody ovuliferous scales and zygomorphic cones, determines the pine as one of nature's most remarkable handiworks. In some species of the Juniperaceae, as in *Biota*, the oriental arborvitae, the embryogeny is even more peculiar than in the pines. The egg begins to develop about 40 embryos with long thread-like suspensors so that the whole group looks like a tiny mass of thread. A single one of these 40 fission embryos finally develops in the maturing seed. This represents about the extreme of embryo development, whether plant or animal, and appears in the highest family of the Pinales. In *Juniperus* one meets with an enormous branching abliity in some species and a minute, colored, berry-like cone with carpels permanently fused at maturity and developing a single seed in the highest species. In *Taxus canadensis* Marsh., one of the culmination types of the Taxales, the peltate stamens come to the same general form as the sporophylls of Equisetum, which an extreme Darwinist might regard as a conclusive case of mimicry. The reduction of the carpellate flower to a single ovule on a vestigial carpel lacking a blade and the development of the bright red fleshy aril around the seed are also unusual and extreme developments.

The highest class of Gymnospermae, the Gneteae, contains one of the most bizarre plants in the plant kingdom. *Welwitschia mirabilis* Hook. f. of the South-west African desert has but two great, ribbon-like, foliage leaves that grow from the base during the entire life of the individual and finally split into numerous narrow segments. The terminal bud becomes determinate when these first two foliage leaves have been produced and only reproductive buds are produced later. This species has a large number of other extraordinary characteristics which tend to make it one of the most remarkable plants in the world.

The flowering plants, or Anthophyta, are the highest and most complex of the plant phyla. They have a complement of 100 or more fundamental potentialities common to all the species of the many phyletic lines or series into which this greatest of plant groups has segregated. Thus unusually large numbers of extraordinary structures have evolved. Only a few of these can be mentioned here to illustrate the general principle. At the top of the Helobiae, the lowest subclass of monocotyls, is that extremely interesting species, *Vallisneria spiralis* L. It is an aquatic plant with long ribbon-like leaves, has the carpellate flower on a very long spirally coiled peduncle which reaches the surface and after pollination the fruit is drawn down by this coiling peduncle and ripens under the water. The staminate inflorescence has a short peduncle with numerous minute flowers about the size of a pin head. These flowers are abscissed and float on the surface and their dehiscing stamens thus come in contact with the receptive stigmas of the carpellate flowers. It is difficult to imagine a more unique method of pollination.

The Araceae and Lemnaceae are advanced families of the Spadiciflorae which also include the palms and Pandanales. One of the extraordinary species is *Alocasia odora* (Roxb.) C. Koch, which has a powerfully odoriferous organ at the top of the spadix and a spathe that is separated in the middle by the development of a corky layer which finally causes the outer end to wither away while the lower end becomes thick and fleshy, forming a tight compartment around the zone of carpellate flowers. This bottle-like structure fills with water secreted on the inside in which the fruit develops. A number of related species have similar characteristics. Among the duckweeds (Lemnaceae) is the genus *Wolffia* which contains the smallest species of seed plants. It has a minute egg-shaped body, which floats on the surface. Its lack of roots and leaves, together with other extreme simplifications, is probably caused by a large number of acquired, inhibitory, hereditary factors. It possesses an extreme ability for vegetative multiplication, the joints separating from each other as rapidly as they are produced. This vegetative multiplication proceeds at such an enormous rate that myriads of individuals may be produced in a favorable season. Dr. L. E. Hicks found that in the drought year of 1933, a single acre in Buckeye Lake in Ohio contained a thousand times as many individual plants of *Wolffia punctata* Griseb. as there are human beings in the whole world.

The Glumiflorae are a rather highly specialized group of plants, the Cyperaceae a lower and the Gramniaceae a higher family of the group. Among the Cyperaceae an extreme development is found in *Eriophorum viridicarinatum* (Engelm.) Fern. and related species in which the ordinary perianth is replaced by a great number of elongated bristles, much like the pappus of many composites. The genus *Carex* has an odd sack-like structure around the ovulary which is not present in any of the lower sedge genera nor in any of the grasses. In such advanced species as the hop sedge (*Carex lupulina* Muhl.) the style is elongated and bent at the lower end into a peculiar double curve. The more advanced tribes of grasses show many exceedingly interesting developments. In the Agrostideae, *Stipa pennata* L. has a fruit with a sharp point at the base and a large twisted and bent awn with a flexible, plume-like end about 12 inches long. Among the oddities in the Panicatae may be mentioned the species of *Cenchrus*, or sandburs, in which the pairs of spikelets are enclosed in a bur representing a cortical outgrowth of tissue covered with rigid, retrosely barbed prickles. In the highest tribe, the Andropogoneae, there are many remarkable plants. Teosinte (*Euchlaena mexicana* Schrad.) has husks covering the carpellate inflorescence, long hair-like styles or silks, and a most peculiar, bony and polished, box-like structure, composed of a rachis joint and an outer empty glume serving as a lid. This box contains the carpellate spikelet and mature grain. The most advanced and extraordinary grass is the Indian corn (*Zea mays* L.) with prominent prop-roots, extreme dimorphism between carpellate and staminate inflorescences, the ear and its cob enclosed in a highly evolved husk, the very long styles or silks together with very long, rapidly-growing pollen tubes, and finally with the highly developed caryopsis or grain containing in different varieties a complex assortment of endosperms of various colors—including flint, waxy, sugary, flour, starchy (dent), and pop varieties. The evolution of the grasses has culminated in a profoundly unique and useful plant.

Near the upper levels of the Liliales are the rushes and here again one finds a unique structure in some of the higher species, as in *Juncus militaris* Bigel. and *J. acuminatus* Mx., in which the leaf blades have a series of transverse diaphragms. In the Tillandsiaceae, *Dendropogon usneoides* (L.) Raf., the Spanish-moss, is an extraordinary plant in many respects. It is one of the most extreme types of epiphytic plants. The stem and very slender leaves are closely covered with translucent, silvery-scurfy, ovate-lanceolate scales, peltately attached, with an oval somewhat glandular area above the point of attachment. The stem is very slender and spirally coiled and flexuous, hanging in clustered festoons from the branches of trees. The leaves have also attained the determinate limit in arrangement, being alternate two-ranked. A very remarkable structure is shown by the very long funiculus of the seed, which splits up into a cluster of fine threads. In the Eriocaulaceae, the most extreme family of the Liliales, the flowers are minute and are collected into disk-like heads which look much like the heads of some Composites. Some species, as *Syngonanthus anthemidiflorus* (Bong.) Ruhl., have enlarged, spreading, involucral bracts causing the inflorescence to simulate an *Anthemis* belonging to the sunflower family. The Eriocaulaceae also contain various species having their corollas transformed to a ring of hairs between the calyx and gynecium. One of the most extreme species with this peculiarity is *Lachnocaulon anceps* (Walt.) Morong.

In the Iridaceae there is a most remarkable flattening, in some species, of the leaves and aerial stem. This flattening is extreme in some species of *Sisyrinchium* and *Marica*. Species of *Iris* show extreme oddities in the petaloid stigmas and hairy crests on the sepals. Some species also have an extreme development of the solid, epigynous hypanthium, a rare structure in the flowering plants. In the two higher families Cannaceae and Marantaceae, of the Scitaminales, the flower is of the zygomorphic type but has in addition developed an inequilateral form, having thus only a half-fertile stamen, the other half being petaloid.

The Orchidaceae represent the most advanced plants among the Monocotylae with the most complicated accumulation of hereditary potentialities. In this family there are many odd and remarkable structures in the flowers, leaves and roots. An unusual development appears in some genera. The pollen is organized into definite bodies or pollinia which are more or less pear-shaped and may have a little stalk or caulicle with a viscid disk or gland at the base. These disks stick to insects visiting the flowers and the pollen is thus carried about. Advanced types of pollinia are found in the following genera: *Orchis*, *Galeorchis*, *Lysias*, *Tipularia*, *Coeloglossum*, *Corymbis*, *Ponthieva*, *Stanhopea*, and many others.

The Dicotyls number at least four times as many species as the Monocotyls and show a correspondingly larger number of extreme and peculiar developments. On a rather advanced level of the Thalamiflorae are the species of the genus *Euphorbia*, which is now usually divided into a considerable number of smaller genera. The flower cluster is a cyathium which in some cases simulates a single flower in appearance very closely, as for example the cyathium of *Tithymalopsis corollata* (L.) Kl. & Garcke. The species of *Chamaesyce* have opposite two-ranked leaves and alternate two-ranked branches, a very unusual culmination type but also present in the related Zygophyllaceae as in *Tribulus terrestris* L. A most extreme type of cyathium is present in *Pedilanthus tithymaloides* (L.) Poit. Some of the fleshy forms of Euphorbia have bodies that mimic in a remarkable manner the forms and characteristics of the American Cactaceae, including the spines and loss of leaves. Among the extreme types are *Euphorbia obesa* Hook. f. and *E. meloformis* Ait. with bodies more or less spherical in shape.

Near the end of the Thalamiflorae are the blue violets with their showy flowers on very long peduncles that produce little or no seed; but the same individuals develop cleistogamous, apetalous flowers and these are very fertile, producing seed abundantly. In spite of this and numerous somewhat similar cases, some botanists still continue the old delusion that showy flowers are the result of natural selection. In the not distantly related passion-flower (*Passiflora*) there is a special structure developed in connection with the corolla, the so-called corona.

In the Piperaceae, whose systematic position is somewhat doubtful but which represent an advanced condition of flower and inflorescence, we meet with that unique phenomenon in the angiosperms, the 16-celled embryo-sac, present in some species of *Peperomia*. In these female gametophytes multiple fusion of numerous embryo-sac nuclei takes place to produce the primary endosperm nucleus. In one species fourteen nuclei are known to fuse. If a sperm nucleus is also involved, the following endosperm nuclei, numbering about 40, would have a 15-ploid chromosome constitution instead of the usual triploid condition.

The milkweeds belong near the end of the series of Polemoniales. in the Tubiflorae. These plants have evolved a remarkable specialization of the andrecium. The pollen of the milkweeds (*Asclepias* and other genera) is massed together in pollinia which remind one of the massulae in the microsporangia of *Azolla* and the pollinia of orchids. In the milkweeds the two sacs of pollen are joined together by a peculiar connecting piece with a slit in it, in which the foot or proboscis of the insect is caught and thus the pollinia are pulled out of the anthers and carried away. This highly elaborated mechanism is so inefficient that usually in our common milkweed (*Asclepias syriaca* L.), even in the presence of abundant swarms of pollinating insects, less than one in a hundred flowers is ever properly pollinated. The Asclepiadaceae also contain some rather extreme forms with succulent stems and minute leaves, comparable to those of the Euphorbias, cacti, Mesembrianthemaceae, and a few composites.

Near the top of the Scrophulariales are the bladderworts (*Utricularia*) which bear on their leaves, under the water, little bladders which have been designated as the most remarkable structures in the plant kingdom, comparable somewhat to the complex organs of the higher animals. One of the most perfect type is found in *Utricularia macrorhiza* Le Conte. These little bladders are provided with entangling and irritable hairs around the mouth and with a trap-door on the inside. The bladders are contracted in the resting condition and when an unlucky little plant or animal swims up and accidently comes in contact with the irritable hairs, the bladder expands suddenly and the victim is sucked in through the mouth to be definitely imprisoned by the closed trap-door.

In the closely related order, the Lamiales, the highest family is represented by the Lamiaceae and one of its extreme genera is *Salvia*. The species of *Salvia* have evolved a most remarkable andrecium which in the more advanced forms consists of two stamens with only one half of the anther fertile, the other half being developed into a long sterile lever attached to the stamen filament by a movable joint. The whole apparatus represents a very ingenious pollen brush which brushes the back of any insect seeking nectar in the base of the flower. This is without doubt a useful mechanism and works efficiently but other species of the mint family which have no such highly elaborated mechanism for pollination are just as successful as the sage.

Among the Amentiferae, which represent an extreme evolutionary series, apparently distantly related to the lower Calcyflorae, one again finds numerous unusual characteristics. Among these may be mentioned the fruit of the common fig, (*Ficus carica* L.) the woody cup below the acorn of the oaks (*Quercus*), and somewhat similar developments in related genera. The cone-like fruit of alder (*Alnus*) is also remarkable and somewhat similar developments are found in certain Proteaceae. Probably the most unusual manifestation in this highly advanced subclass is the presence of chalazogamy in various genera, as in *Juglans*, *Carya*, *Casuarina*, *Corylus*, *Betula*, etc., in which the pollen-tube, instead of passing along the usual route through the micropyle, penetrates through the base of the ovule. This action indicates that the pollen-tubes have attained the extreme of parasitic ability.

The Myrtiflorae also contain highly evolved groups and one can easily find odd and unique structures among them. In the cacti are developed many unusual forms of body and spine. Some of the forms are very extreme and simulate the bodies of Euphorbias. Some species of *Opuntia* have very sharp spines with retrorse barbs which, however, are covered with a papery sheath. This sheath develops an abscission zone at the base and is thus easily removed from the spine.

Among the Cucurbitaceae are various extraordinary fruits, such as the squirting cucumber (*Ecballium elaterium* (L.) A. Rich.), watermelon (*Citrullus*), etc. There is an authentic record of a watermelon attaining the enormous weight of 183 lbs. In this region of the plant kingdom also occurs that remarkable monstrosity, the largest flower in the world, produced on a parasitic plant with inconspicuous body and without green leaves, *Rafflesia arnoldi* R. Br. (Rafflesiaceae). This flower weighs about fifteen pounds and measures a yard across. The petals are about a foot in length and vary in thickness from three-fourths of an inch in the thickest part to one-fourth of an inch in the thinnest part. There are several other species of Rafflesia with most remarkable flowers.

Another family of this subclass is the Mesembrianthemaceae which has a number of genera with extremely unique body forms, some of which are supposed by teleologists to simulate pebbles, as in *Mesembrianthemum ficiforme* Haw. Extreme forms of plant body are present in the genera *Lithops*, *Frithia*, *Fenestraria*, etc. The species of Fenestraria have "windows" at their leaf-tips which project out of the ground. The compact forms of these extreme Mesembrianthemums suggest the somewhat similar forms appearing in many species of cacti which seem to be distantly related to them.

The mangrove (*Rhizophora mangle* L.) belonging to the Rhizophoraceae, has several extreme characteristics. The seed sprouts in the fruit on the tree and when the embryo is quite large it drops down into the mud or water. The mangrove also has a remarkable, aerial root system which forms a complex branching prop about the base of the trunk.

Among the Caprifoliaceae are a number of species in various genera that produce twin flowers, as in some species of *Lonicera*, *Linnea*, and *Kolkwitzia*. The latter is also bizarre in producing an elongated neck between the ovulary and calyx which spreads out horizontally somewhat like the pappus bristles of some composites.

In advanced Angiospermae with complex and specialized complements of hereditary factors, the sequence of differentiation in determinate shoots, as in the inflorescence axis or the flower receptacle, is often changed from the primitive type, where the differentiation gradient follows the order of the cell lineage, to a new sequence. In *Campanula*, as in *C. americana* L. and other species, the spicate flower cluster begins to bloom at the base in the usual way but at the same time the very tip flower also comes into bloom. The remaining flowers of the spike develop in the normal sequence from the lower level to the terminal flower which has passed its blooming period for some time. In the elongated head of the wild teasel, *Dipsacus sylvestris* Huds., the blooming begins in the middle and proceeds toward the base and apex at the same time. A similar sequence is followed in the blooming of the ear and tassel of Indian Corn, *Zea mays* L. In various types of advanced flower clusters, as in *Lacinaria* and in *Nabalus asper* (Mx.) T. & G., the heads begin to develop and bloom at the tip of the stem and continue downward to the base. Many such odd gradients develop in various advanced groups.

The highest family of plants is, without question, the Cichoriaceae. Here the genus *Tragopogon*, to which the common salsify belongs, has evolved a truly wonderful pappus which forms a large parachute on the fruit. This parachute closes up in wet weather and expands when dry. It also has an abscission layer by means of which the plane of the parachute is finally separated from the long stalk that connects it with the achene. In the common dandelion (*Taraxacum officinale* Weber) there is a similar, although less elaborated, parachute, and in addition a much more remarkable development. The plant has evolved diploid parthenogenesis, or virgin birth, for all of its offspring. All the seeds are developed without fertilization and thus the pollen and pollination by means of visiting bees or other insects are of no use whatever to the plant. In addition to these two extraordinary characteristics, the dandelion has the unusual ability to split into new individuals vertically after a certain age is attained and to be rejuvenated during the process, so that after the splitting the juvenile type of leaves is again produced. It is also able to produce a new individual from any little scrap of the root. The dandelion not only has these extreme characteristics but also has one of the most complex if not the most complex complement of general and special hereditary potentialities of any plant in the plant kingdom.

The same principle of the evolution of extraordinary characters in the higher levels is also operative in the various animal series. In the insects, for example, the polymorphic development of members of colonies of ants, wasps, and bees and their instinctive social reactions are extraordinary characteristics. The unusual nest-building abilities of many of the higher birds as compared with the more primitive species or with the reptiles also represent the same evolutionary manifestation.

Man himself is the most remarkable example of the working out of this principle of extraordinary developments at or near the ends of phylogenetic lines, and thus occupies a most unique position among all living things. Man represents the determinate limit of many evolutionary, progressive series. He has attained the limit in his perfectly erect position. He has extreme specialization of fore and hind limbs, suitable for very different activities. The development of the arms, and especially of the hands, of man into remarkably mobile instruments makes them fit alike for feeding the mouth, making tools, playing the most complicated music, writing, and the creation of all art. Man's intelligence would be of little avail without these wonderful organs. Man's face has also reached the limit of position, as compared with the lower animals, in being shifted from a position in line with the dorsal side of the body to a position in line with the ventral side. This shifting, along with the expansion of the brain, has placed the brain instead of the mouth at the end of man's body. Man's voice apparatus and mouth are also extraordinary developments and can be employed in a multitude of ways in addition to their use in speaking and singing. The specially gifted and developed human singer has no compeer among all the vocal animals of the earth.

It is clearly evident to the contemplative scientist, as stated by Henry Fairfield Osborn, that the human brain is the most profoundly marvelous and mysterious object in the whole material universe. It is in some mysterious manner the instrument of the mind, subject to the will of the self-conscious, reasoning, creative, and inventive personality. This small body is more complicated in units of structure or cells and infinitely more complicated in interaction of these units than our entire, heavenly galaxy of suns. It has been estimated, on a conservative basis, that there are over twelve billions (12,000,000,000) of cells in the human brain alone, and it is evident that the self-conscious personality, my ego, controls this amazing mechanism and other billions of cells of the body to a definite purpose while this sentence is being written. There are about two billions of human individuals on the earth at the present time. Thus, one brain contains at least six times as many structural, biological units as the entire population of the world. One could make a present of six of his brain cells to every man, woman, and child now on the earth. Moreover, each cell has a nucleus with forty-eight chromosomes which can be counted under the microscope and which contain the Mendelian hereditary potentialities or genes. Thus, there are in the brain more than half a trillion chromosomes which, because they form the most important part of the living substance, must certainly be involved in this control of the intelligence and will, not only in producing the inconceivably complex co-ordination involved in the mechanical and chemical activities but also in the production of the conscious thoughts themselves.

Comparing the human brain still further with the amazing numbers which astronomers give of the suns in the starry heavens, the brain does not take any subordinate position in so far as mere numbers are concerned. About one billion stars are within reach of the 100-inch telescope on Mt. Wilson, California. Thus the brain contains more than twelve times as many biological, cell units as the number of stars visible in this great telescope. According to some estimates there are forty billion stars (suns) in our own galactic system. Thus since a man has more than 576 billions of chromosomes in his brain, he carries about in his cranium as many of these important biological units as there are suns in fourteen galactic universes of the size of our own. Carrying this mathematical diversion a little farther, it may be stated that it has been estimated that the normal human body contains twenty-six trillion cells. Thus, with forty-eight chromosomes in each cell, the total number of chromosomes in the human body reaches the marvelous number of more than one quadrillion (1,248,000,000,000,000). In round numbers we can say that our bodies contain as many cells, or structural, biological units as the calculated suns contained in 650 galactic systems the size of our own milky way, and as many chromosomes as the suns of 31,200 galaxies. Thus we can justly exclaim with the Psalmist of long ago: "I am fearfully and wonderfully made."

The mind through the action of the brain recreates the universe from a few simple irritations of nerve endings on the surface of the body, a few pressures on the skin, a few vibrations in the ears, a few rays of light impinging on the retina of the eyes, a few chemical stimuli on the mucus membranes of the mouth and nostrils—these simple irritations impinging on the sensory nerve endings set up nervous impulses which are conveyed along the nerve strands not as touch, sight, sound, taste, or smell but simply as electrical or mechanical processes to be transformed in the hidden chambers of the brain cells into sensations and mental pictures from which each person, through the action of the reason, constructs an intelligent system, a world, a cosmos, a universe. Thus we attain to a knowledge of the outside world as a reality and also to the apprehension of our own selves as distinct from all that surrounds us. This is the determinate limit of the evolutionary process. Then there is another great mechanical marvel, entirely incomprehensible when compared with ordinary mechanisms, namely that sometimes persons have lost considerable portions of both frontal lobes of the brain, with the destruction of myriads of brain cells, without impairment of their intelligence after the wounds were healed, so long as at least one lobe has not been seriously damaged. However, something that poisons or injures a large part of the cellular structure, as for example the presence of narcotics or alcohol, causes a decided confusion in the action of the mechanism. Nor must we forget the fact that all these human brains and personalities are unique. Nature makes an elaborate mould in which to mould one human individual and then throws it away. Each individual becomes a decidedly unique thing in the universe never to be exactly repeated, not even in identical twins. It is evident that a humanity of closely similar individuals would, from a philosophical point of view, be a profound miscarriage of the creative, evolutionary process.

The development of individuality becomes quite pronounced in the higher animals, but is, of course, enormously less than in human beings. Thus our principle of the evolution of unique and extraordinary characteristics at the ends of the progressive, phylogenetic series is seen to be one of the most important and fundamental aspects of the evolutionary process. The result has been an organism with the capability of promoting extreme good or extreme evil in the realm of nature and man. This problem must be a primary concern of scientific study as well as of moral and spiritual discipline, if the improper use of intelligence and science is not to destroy the very foundations of civilization, through the progressive invention of mechanisms which can be employed for evil and destructive purposes by those who may obtain political and social control. Finally, it must be especially emphasized that the human self-consciousness is a unique phenomenon in the biological realm. A higher animal may think but there is absolutely no evidence that it knows that it is thinking or that it knows of its own existence. If it did it could easily tell us so by word or sign. But not one animal idea has ever been recorded.

The extraordinary developments in man and the higher animals are not to be explained on special teleological grounds. Teleological hypotheses receive no confirmation in fact from a scientific study of the taxonomic systems in relation to their environment. This fact is evident to any one who has the merest acquiantance with the taxonomic system. Mice and men all live in essentially the same environment, and mice usually insist on living in man's immediate domicile; and for mere physical survival men need no more brains than do mice or elephants.

The extraordinary developments, whether mental or physical, are a part of the general evolutionary process and represent peculiar products appearing in advanced members of phylogenetic series, especially in organisms with very complex hereditary systems. They are the results of an intrinsic, mutative process that has been operative in the protoplasm during the geological ages and which we designate, scientifically, by the general term, creative evolution.